11-109

BEFORE THE

Federal Communications Commission
Washington, DC 20554

In the matter of

LightSquared Subsidiary LLC File No. SAT-MOD-20101118-00239

Request for Modification of its Authority for an Ancilliary Terrestrial Component

Comments by Charles W. Rhodes

I, Charles Rhodes, was the Chief Scientist of the Advanced Television Test Center Inc. throughout its lifetime, 1988-1996. I was responsible for the technical aspects of the testing of Advanced Television Systems in the laboratory facilities of the ATTC which I was also responsible for. In 1995, we tested the Digital TV System devised by a consortium of firms who has developed proprietary and competitive systems to replace the analog TV system (NTSC) adopted by the FCC in 1954. Under the leadership of Mr. Richard Wiley, chairman of the Industry Advisory Committee to the FCC in the matter of Advanced Television Systems, these firms worked to devise one digital TV system to be proposed by the industry to the FCC.

In that work, we were vitally concerned with the possibility of interference between the analog and DTV signals during the transition from analog to digital transmission. During that transition, DTV signals would transmit on channels not already in use. We were especially interested in the DTV-DTV interference after the transition.

Since retirement, I have remained interested and active in the progress of DTV during the transition, and more recently, in the new all-digital world we helped create. I have published a number of technical papers on the topic of DTV-DTV interference based upon my own experimental investigations.

When I learned of the plan for terrestrial broadcasting in the MSS band adjacent to the space-to-earth segment of the GNSS band, I realized that there was a potential interference problem similar to that of multiple DTV signals on nearby channels that I had studied and published on.

In my own laboratory, I have conducted a series of simulations of the three phases of the LightSquared scheme using multiple DTV signals. This work was done in May & June 2011. The results convinced me that there would be jamming of GPS receivers by the proposed terrestrial transmissions in the MSS Band. It came as no surprise that the Technical Working Group (TWG) reported similar findings for actual GPS receivers with the actual LTE Signals being radiated in the MSS Band.

Simulations of higher order distortions which produce noise in the GPS Band

I believe that the interference reported by the TWG for two 5 MHz LTE signals in the MSS Band was primarily due to third order inter-modulation products generated by that pair of LTE signals. The recent proposal by LightSquared to initially radiate only one LTE signal in the MSS Band (see above) will not result in third order distortion products which fall within he GPS receiver passband. However, my simulation has shown that there will be higher order distortion products which will fall within the GPS Band as shown in my Figure 1 attached.

The GPS system employs Direct Sequence modulation which uniquely permits reception of faint signals well below the noise generated by the receiver. [1]. GPS signals are received at about – 130 dBm. This compares to the minimum usable received DTV signal (which does not use Spread Spectrum technology such as Direct Sequence modulation) power of – 84 dBm. This is 46 dB less power required for GPS reception than required for DTV reception.

The signal power of the planned implementation by LightSquared which may enter GPS receivers near a LightSquared transmitter may be – 30 dBm. The received GPS signal is at – 130 dBm, a difference of 100 dB.

I have also simulated the single ten MHz wide LTE signal in the MSS Band from 1526 MHz to 1536 MHz to see if it might also cause interference to GPS reception as shown in Figure 1.

This interfering signal would overload many GPS receiver input transistors and they will generate higher order distortion products some of which fall in the GPS Band as shown in Figure 1.
Marker # 1: 1526 MHz (simulated) Marker # 2: 1536 MHz (simulated) and Marker # 4: 1575 (simulated). .

My colleague, Mr. Linley Gumm has simulated this same problem on a Computer and obtained similar results. This tends to confirm the simulation carried out in my laboratory with multiple DTV signals.

Simulation Strategy

These simulations used two DTV signals on channels 30 and 31 in the UHF Band. The bandwidth between – 3 dB points on the TV signal are 5.38 MHz. The two signal's passband extends from 566.310 MHz to 577.07 MHz (10.76 MHz bandwidth). The simulation offset between these is 959.69 MHz. The lower edge of the channel 30 DTV signal is 566.31 +959.69 MHz = 1526.00 MHz. The upper edge of the second DTV signal is 567.07 MHz + 959.69 MHz = 1536 MHz. The GPS band center = 1575.42 MHz so in my simulation it is 1575.42 MHz – 959.69 MHz = 615.73 MHz. The spectrum plot shows the GPS bandwidth of +/- 12 MHz centered on 1575.42 MHz.

Conclusions that can be drawn from these simulations

What this simulation demonstrates is that the noise floor in the simulated GPS band is from 8 to 18 dB above the instrumentation noise floor. If we take the average of 13 dB across the GPS Band, that is the jamming effect of this signal. This 13 dB increase in the noise floor across the GPS Band is not the only factor that will cause jamming of GPS reception. The other cause and it could be the more significant cause is called de-sensitization. This is another odd order distortion product but it applies to all signal frequencies. The undesired signal received power can exceed that of the GPS signal by 100 dB. It is most unlikely that any known transistor will not suffer de-sensitization when two signals as different in power as this are present. Even with a filter between the antenna and the RF amplifier transistor, the power difference between the LightSquared signal and the GPS signals is so great that some de-sensitization will be experienced.

What cannot be concluded from these simulations

The Low Noise Amplifier transistor used in GPS receivers is usually biased to minimize noise, not to maximize dynamic range. Furthermore, few such devices are specified for higher than 3rd order inter-modulation performance. As shown above, higher order non-linearities in these transistors can generate higher order distortion products which fall within the GPS Band resulting in jamming. Only by laboratory testing of GPS receivers can their robustness to jamming be determined.

Future Increases in Radiated Power in the MSS Band

If LightSquared were allowed to increase their EIRP, whatever de-sensitization there is would be increased. A 3 dB increase in EIRP would result in a 9 dB increase in de-sensitization because this is a 3rd order distortion product. That would probably end the usefulness of most GPS receivers.

Filters for mitigating jamming

If a filter were available that could be placed at the antenna so as to reduce the Undesired signal by 40 dB, it would still be 60 stronger than the GPS signal. Even with a 40 dB filter, I believe that there will still be some de-sensitization of GPS receivers. The extent to which de-sensitization and high order inter-modulation products impact the reliability of GPS reception has not been determined. This filter must not attenuate the GPS signal by more than say 1 dB because that amounts to a de-sensitization of the GPS receiver of 1 dB. There are filters that can provide the out-of-band rejection (40 dB) but to the best of my knowledge their insertion loss exceeds 1 dB.

Reducing signal overload by increasing current in the LNA

The dynamic range over which a transistor operates in a linear mode (does not generate distortion products) can be made larger by biasing that transistor to operate at much higher currents than are commonly employed in portable GPS receivers and in cellular telephones. In short, better performance concerning interference is possible, but at a considerable cost in the time the battery in hand-held receiving devices can operate before re-charging.

Conclusions

The testing performed so admirably by the TWG was designed to provide Pass / Fail results. It was not the intent of those tests to determine the mechanism(s) by which the system failed. It appears to the writer that non-linear distortions in the GPS receiver LNA are the causes. De-sensitization lowers the GPS signal power, while higher order intermodulation products increase the noise floor in the GPS Band. The relative importance of these two causes is unknown. It would be extremely dangerous for the FCC to proceed with Final Authorization for LightSquared to proceed to build its infra-structure based on what is known about GPS receiver performance with one ten MHz LTE signal at 1526-1536 MHz. Further testing is needed.

Charles W. Rhodes July 28, 2011

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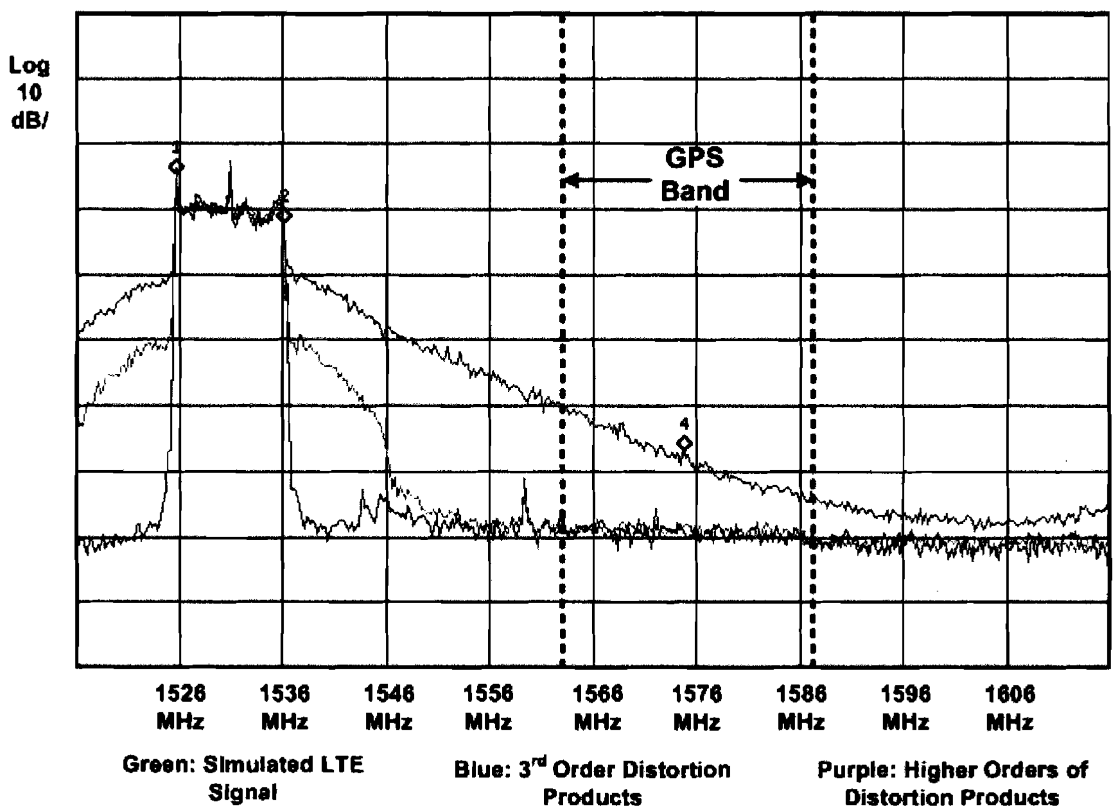

Figure 1. Simulated spectrum of 10MHz LTE signal 1526-1536 MHz